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Effects of stemflow on the mycorrhiza of beech (*Fagus sylvaticus* L.)

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INTRODUCTION

Acid precipitation with the resulting acidification of forest soils and related soil processes are recognised as a serious threat for soil biota and forest trees in the northern hemisphere. Changes in mycorrhiza due to soil acidification are postulated by several authors and observed in German forests by MEYER (1985) as a decrease in number and diversity of mycorrhizal types. These observations are supported by WINTERHOFF and KRIEGELSTEINER (1984) who noticed a general reduction in fruitbody production of certain mycorrhizal fungi in southern Germany, and by JAHN *et al.*, (1967) who did find fruit bodies of certain acidophilic fungi restricted to stemflow areas in a German beech forest on a calcareous site. The same phenomenon has been described for *Luzula albida* by GLAVAC *et al.*, (1971) and related to differences in soil acidity. In beech forests about 13% of the total annual rainfall reaches the soil through stemflow (fig. 1) seeping away near the stem base. KOENIES (1983) describes some of the resulting soil changes.

Under the influence of stemflow a model system has been developed showing a gradient in soil conditions concerning acidification. Roots and mycorrhizae within this system probably belong to a large extent to the same individual tree, exposed to identical above ground injuries through air pollution and other abiotic and biotic factors.

This paper describes variations observed in mycorrhiza type and composition under the influence of stemflow in beech, and tries to relate them to soil acidification.

METHODS

A 120-year old beech stand, situated in the North German Eggegebirge, was chosen as a research area. Being the first mountain ridge east of the Ruhr area, it is quite heavily influenced by air pollution emitted in that industrial region. Forests in the area are severely injured (SPELSBERG, 1983) and reproduction of beech is inhibited especially under the influence of stemflow as reported by HUETTERMANN and GEHRMANN (1982).

Characteristics of the stand are as follows :
rainfall : 1200 mm (530 mm/a during the vegetation period).
main wind directions : NW-W-SW.
exposition : NW
inclination : 30° (site 1), 10° (site 2).
soil types : brownearth-rendzina (site 1), brownearth (site 2).

10 soil samples (upper 5 cm of mineral soil) were taken with an 8 cm auger at the intersections of a screen laid below a dominant beech tree in site 1, according to fig. 1. Additional samples from 4-year old trees were taken at site 1 and 2.

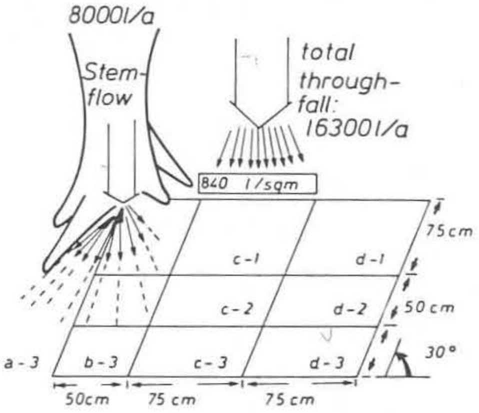

Figure 1. Water balance and sampling-schema in the stemflow area on site 1.

Fine roots were extracted by wet sieving as described by MARX (1965). Mycorrhizal types were characterized by mantle colour and organization, branching habit, surface structure, and intensity of radiating hyphae, following proposals by ZAK (1973).

Soluble Ca, Mg, Pb and Al were measured in the 1:1 soil-water extract using flame AAS (Ca, Mg) or electrothermal AAS (Pb, Al). Soil pH was determined as pH (H_2O). At site 2 only pH measurements were taken to characterise the soil.

RESULTS

By microscopical investigation 11 mycorrhizal types could be distinguished. Main morphological characteristics of the four dominating types are given in table 1. The seven other types found were restricted to single samples and neglected in the following discussion.

Table 1. Gross morphological characteristics of the four dominant mycorrhizal associations found on site 1 and 2.

Mycorrhizal type	Mantle colour	Branching	Radiating hyphae	Mantle structure
1	white	pyramidal	none	pseudoparenchymatous
2(*C. geophilum*)	black	irregular	numerous	pseudoparenchymatous
4	greyish	irregular	numerous	prosenchymatic
11	brown	irregular	few	prosenchymatic

An additional feature of type 4 mycorrhiza is a characteristic excretion of mucilage leading to an agglutination of soil particles with the mycorrhizal complex.

Differences in mycorrhiza type composition could be observed between samples as illustrated in fig. 2 for the types described above. Figure 3 shows the variations in soil parameters measured. A comparison of fig. 2 and 3 indicates correlations between changes in soil parameters and the distribution of dominant mycorrhizal types under the influence of stemflow. This is especially the case for type 1 mycorrhiza being most dominant in samples below the stem base. The soil here is heavily altered under the influence of stemflow and belongs to the aluminium buffer range according to ULRICH's (1981) classification.

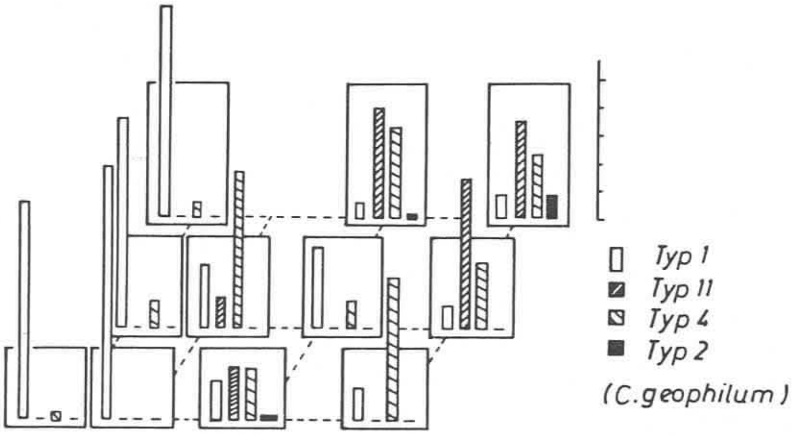

Figure 2. Distribution of four mycorrhizal types under the influence of stemflow induced soil changes (site 1.)

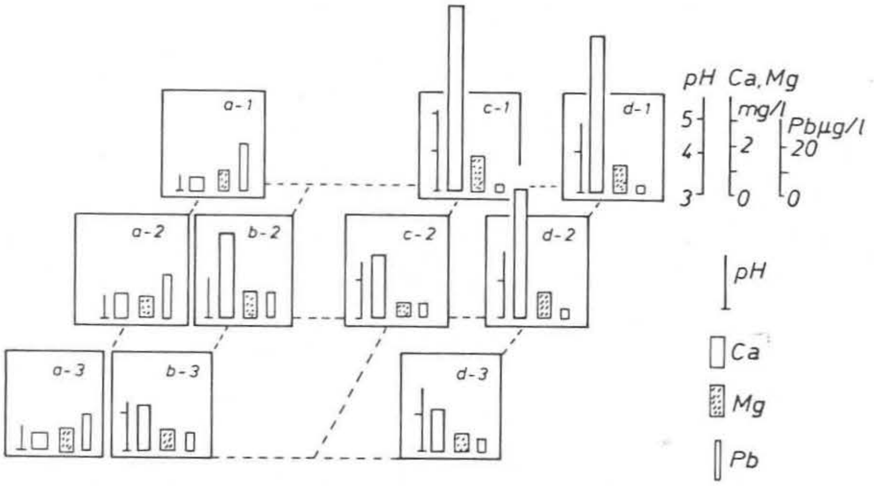

Figure 3. Parameters of the soil solution (1 : 1 soil-water extract) in the vicinity of a beech tree on site 1. (Sampling according to fig. 1).

Only type 1 mycorrhizae showed a linear correlation with the soil parameters measured. The best correlation was found between the logarithmic dominance (1 n (% type 1)) and a) the logarithmic (Ca/Al) ratio with a correlation factor of r = 0.94, b) pH with r = 0.86, c) logarithmic Ca content of the soil solution with r = 0.85 and d) logarithmic Pb with r = 0.84.

The correlation between distance of sampling points and stem base for type 1 was rather poor (r = 0.43). The succession of mycorrhizae with ageing of root systems, as observed by MASON *et al.* (1983), is therefore valued as being of subordinate importance in this investigation dealing with much older trees.

Examined root systems of young trees differ in mycorrhizal composition depending on their origin. On site 1 samples, the mycorrhizal types described for the auger samples showed a comparable distribution in the stemflow area. But variations between stemflow (pH 4.35) and control site (pH 4.75) are overlapped by a horizontal specific distribution of types.

Four-year old seedlings collected near the stem base of older trees on site 2 lack any mycorrhizae. Mainly pseudomycorrhizae without mantle, showing frequent intracellular infections, occurred in the mineral soil with pH 3.54. Outside the stemflow area (site 2) mycorrhizal infection was observed, but restricted mainly to the organic topsoil. Type 1 mycorrhiza reached appreciate amounts in the mineral layer, only in the least acidic sample with pH 3.67.

DISCUSSION

Soil properties such as pH have an effect on the composition of mycorrhizae as has been shown by several authors before (HARLEY, 1937, 1940 ; RICHARD, 1961 ; SLANKIS, 1974). Acidification of soils due to anthropogenic air pollution imposes an additional stress on the organisms involved in mycorrhizal formation. This apparently happens in the stemflow area of beech and leads to marked differences in the mycorrhizal associations. Type 1 mycorrhiza seem to be the only one which tolerates the acidic soil conditions below pH 4 in the stemflow area on the examined site 1. Protective properties of mycorrhizal fungi against adverse soil conditions, e.g. high Al and heavy metal concentrations might be accomplished best by such a type with a very dense mantle structure. Other types, with numerous radiating hyphae establish a much more intense contact with the soil and might be superior for the nutrient supply of the tree, in penetrating a larger soil volume, but possibly being not such a perfect barrier between soil and root cells. It might be for that reason that they are the "preferred symbiotic partners" under more favourable soil conditions with decreasing influence of stemflow on site 1.

Whether type 1 really lack radiating hyphae or these are only less resistant against mechanical damage and therefore lost during isolation has to be questioned. Physiological tests about efficiency in terms of nutrient supply and protection against heavy metal uptake are under investigation and need to be done for the different types.

DIGHTON *et al.* (1986) observed similar variations of spruce mycorrhizae in an acidification experiment, showing smooth types in most acidified and types with radiating hyphae in the control series.

On the more acidic site 2 a limit for mycorrhizal infection might be reached in the inner part of the stemflow area. Here no mycorrhizal fungi seem to be able to form typical ectomycorrhizae. Under the adverse soil conditions, two young trees growing very near the stem base have only formed pseudomycorrhizae, these more likely being parasitic relations than symbiotic ones. HARLEY (1937) frequently found such associations on very acid soils in the Chilterns. According to LUNDEBERG (1960) such features might well be developed due to excess in soil moisture and this should be considered in interpreting these results, because of the rather poor drainage compared to site 1. No investigations have been done upon this point yet.

Cenococcum geophilum, although not a very frequent type, is restricted to less acidic samples on site 1, an observation in accordance with CUDLIN *et al.*, (personal communication), who observed this type in Czechoslovakian forests influenced by air pollution only in the less damaged stands.

Correlations exist between some of the soil factors measured and dominance of certain mycorrhizal types, but no single factor could be isolated by simple statistical means, as being the major responsible one for affecting the mycorrhizal population in the observed manner, and the changes are interpreted as a response to the whole complex of changing soil properties.

DIGHTON *et al.* (1986) discuss increased solubility of toxic elements e.g. Al as a possible reason for changes observed in mycorrhizae. This cannot be confirmed by our data with aluminium showing no correlation with dominance of any mycorrhizal type. But a high correlation with the Ca/Al - ratio indicates some combined effect of Ca deficiency and Al toxicity. A role of Ca/Al - ratio in root disease has recently been shown by ROST-SIEBERT (1983).

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